



Can Gravitational Waves Be Detected

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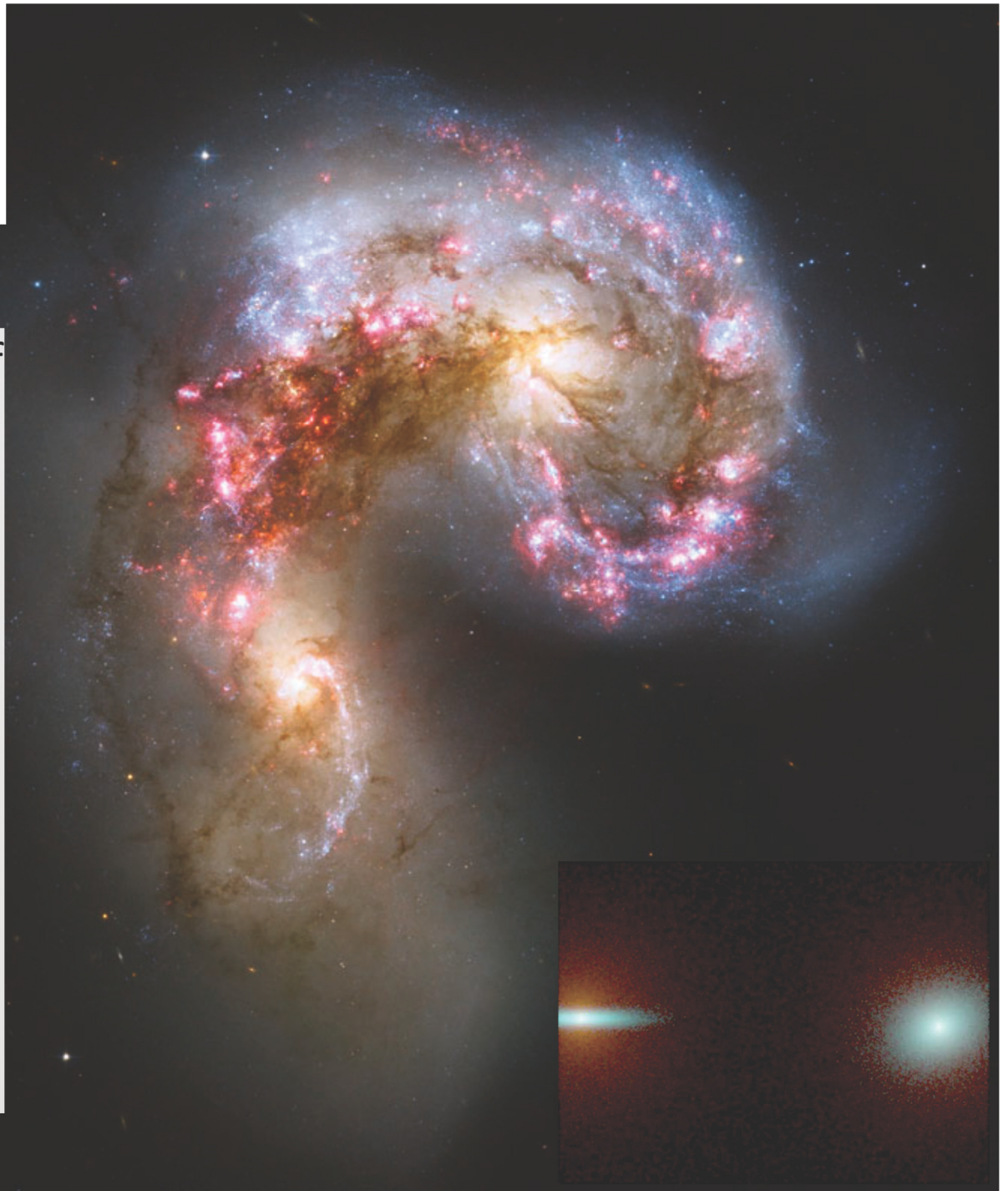
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Part I:

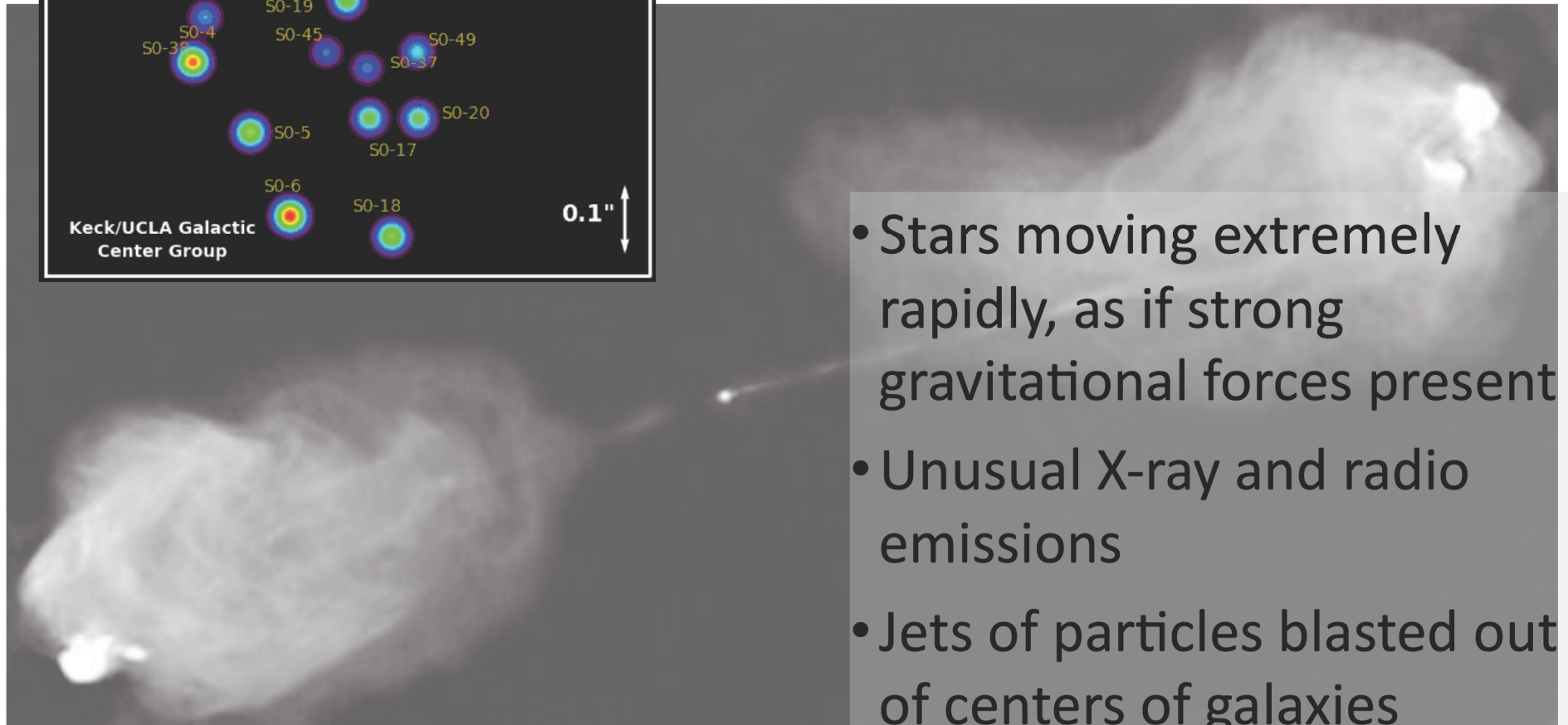
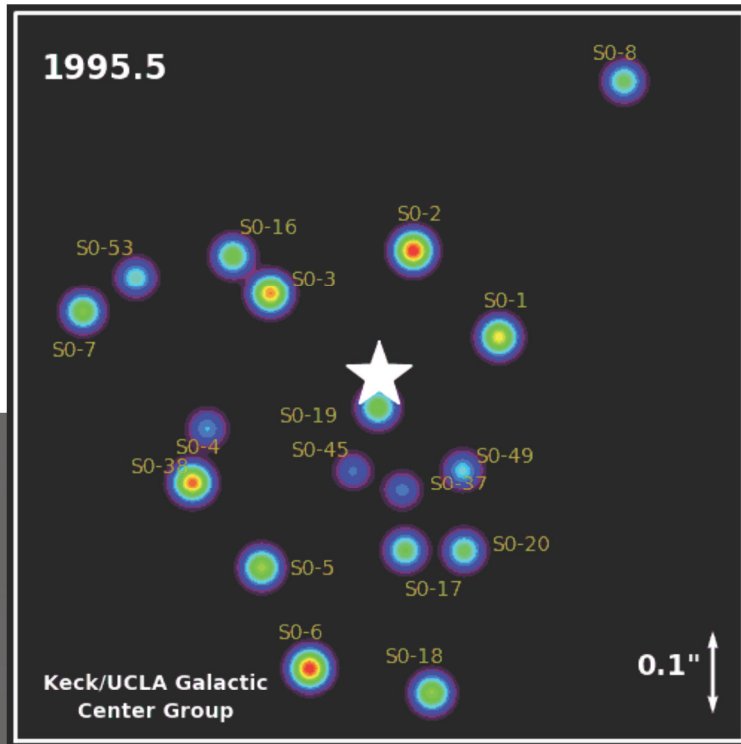
Galaxy Mergers

Apparently important part of galaxy formation

- See clearly disturbed galaxies,
... as if they are colliding.
- See what appear to be remnants of smaller galaxies within the Milky Way,
... as if they've been shredded by the gravitational (tidal) forces of the Milky Way.
- Simulations show galaxies that look like the colliding galaxies that we see.



Supermassive Black Holes in Galactic Centers



- Stars moving extremely rapidly, as if strong gravitational forces present
- Unusual X-ray and radio emissions
- Jets of particles blasted out of centers of galaxies

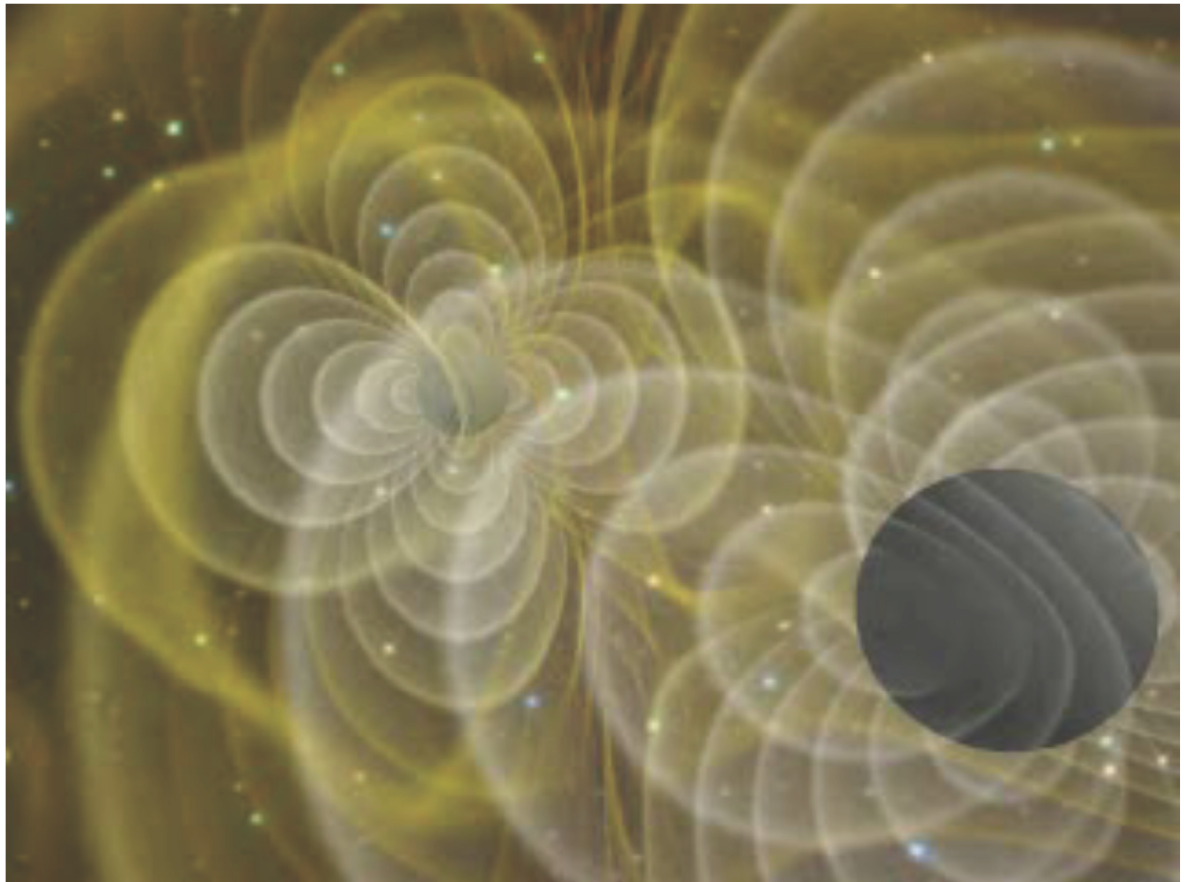
• ...

5 GHz radio image

Black Hole Mergers and Gravitational Waves

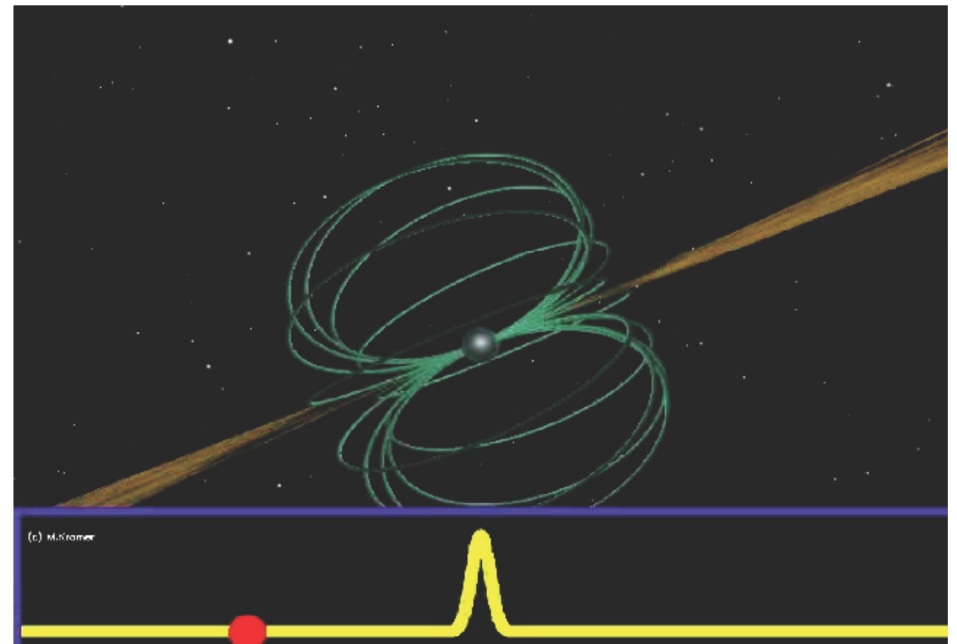
- Galaxies merge.
- Galaxies contain supermassive black holes.
- **Prediction:** Black holes will merge, and *gravitational waves* will be produced.

Einstein's Theory of General Relativity



Part II: Radio Pulsars

- Collapsed remnant of a star much more massive than the Sun
- Comparable in size to Geneva
- Spinning incredibly rapidly
 - ... most rapid approach 1000 rotations per second!
- Strong magnetic fields that beam radio radiation
 - ... similar to a light house
- Extremely precise clocks
 - ... can rival atomic clocks on Earth
- Radio studies from 100 MHz to 20 GHz (and higher)



Question:

Can gravitational waves be detected?

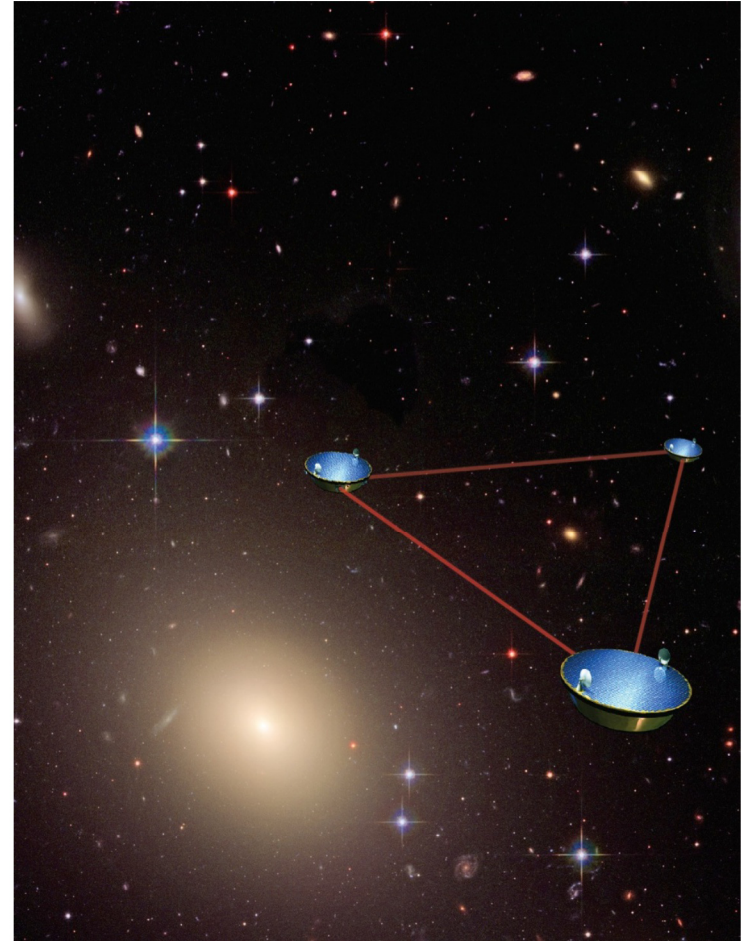
- Gravitational waves (should) affect spacetime.
- Arrival times of pulsars (should be) affected by passing gravitational waves.
- Does precise timing of pulsars reveal effects of gravitational waves?



Question:

Can gravitational waves be detected?

Future space-based mission
using lasers also of interest
to NASA and ESA.



Gravitational Waves and the Radio Spectrum

- Radio pulsar timing programs conducted in UHF band (L-, S bands).
 - Also interested in finding more pulsars ...
 - VHF and UHF bands (P-, L bands)
- Future space-based laser interferometers use spacecraft communication bands.
 - **E-S**: 2110–2120 MHz, 7145–7190 MHz, 34.2–34.7 GHz
 - **S-E**: 2290–2300 MHz, 8400–8450 MHz, 31.8–32.3 GHz

Who cares?

- Gravitational waves are a fundamental, but **unverified**, prediction of Einstein's Theory of General Relativity.
 - Einstein published General Relativity in 1915.
- General Relativity is an integral part of our everyday lives.
 - Satellite navigation (GPS, Galileo, ...)
- Testing General Relativity today is required to produce the technical advances of the next century.